RELATIONSHIPS BETWEEN R&D CONTRACTS AND PRODUCTION CONTRACTS

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PREFACE

This study is an econometric analysis of an aspect of the government procurement process. It analyzes the extent to which companies receiving research and development contracts also tend to obtain procurement contracts.

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I. Introduction

In this paper, published data on total prime contracts and evaluation, development, testing, and research (EDTR) contracts to business firms are used to study the relationship between firms' acquisitions of EDTR contracts and subsequent procurement contracts. In an earlier study using state data, [1], it was concluded that lagged EDTR contract awards explain 73 to 95 percent of the variance in total primes and in total primes minus EDTR awards; that EDTR contracts affect prime contracts with a two to five year lag; and that the type of institution -- business, educational, or other nonprofit -- receiving the EDTR award does not significantly affect the distribution of prime contracts.

Since contracts are awarded to firms and to other institutions, not to states, it is of interest to compare the above results with results obtained from data on a more appropriate level of aggregation -- the firms themselves. The public policy question arising in this context may be contrasted with the implications of the earlier study which emphasized the regional distribution of contracts. The firm data used in the present study allows us to examine the lock-in effect; this occurs when, for a weapons system procurement action, the government negotiates only with the firm which performed the advanced development work. In addition to the possible adverse effects on the government's bargaining position, discussed below, the lock-in effect may encourage mergers by large production-oriented companies and smaller EDTR firms.

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In the next section, lock-in effects and possibilities of mergers are discussed. It is followed by a description of the data, results of the statistical analysis, and some conclusions and directions for further research.

II. Lock-in Effects and Mergers

Several RAND publications (particularly [2]) and [3] and [4] describe the weapons system procurement process in some detail. In general the firm selected to do the advanced development stage of a weapons system procurement is virtually certain to receive the production award. These studies suggest several factors which help to explain this:

1. If a firm must incur a substantial initial investment or extended period of manufacture, or formal advertising would be costly or time consuming, the government may negotiate directly with the firm which performed the development work. In particular, this category includes high starting costs pais by the government or the supplier; preliminary engineering and development work not useful to other suppliers; elaborate special tooling already acquired; substantial time and effort already expended in developing prototype or initial production model; and important design changes which will continue to be developed by the supplier.

2. The government frequently uses the production contract as a reward for development work, paying little profit on the latter, but offering an excellent chance for high profits on the procurement contract if the development is successful. It is argued that the contractor may assign more talented people to the development work and take other steps to perform satisfactorily with the incentive of sizeable profits on a production contract.

3. Preserving the development capability of the firm which performs the design work may require a production contract, especially if low profits are given for development work.

4. Awarding the contract to the development firm to permit organizational continuity may reduce lead times and take advantage of specialization of know-how and skills.

However, as stressed by Hall and Johnson, when the government elects to deal with the firm that did the advanced development it loses the benefits of competition among potential suppliers. Rather than having firms rely on the profits from production contracts, the government could reward development efforts to a greater extent. Further, if the advanced development firm really has an advantage in terms of initial investment or special skills, this should appear in its bid making it unnecessary to confine negotiations to that firm, as has been pointed out by Hall and Johnson, [2].

Another consideration which might argue against the practice of awarding production contracts to the firm which performed the advanced development work, is the possibility that such practice encourages mergers. That is, production-oriented firms might acquire development firms in order to be able to compete effectively for the development contracts, and ultimately for the production contracts. Should these types of mergers be encouraged? A number of considerations have been raised in the literature:

1. Scherer stresses the beneficial competitive effects on performance of correlations between development and procurement contracts, but there is less gain if development contracts are picked up by mergers since companies might not emphasize their own development efforts when merger is an attractive alternative.

2. Kaysen and Turner feel there is evidence that vertical integration may serve to limit competition, as quoted [3, p. 152-3].

3. Peck and Scherer address themselves to the question of whether a diversified company is more efficient than several independent companies. They

do not find that diversified companies are clearly more efficient, and think that economies of scale are difficult to establish. Such efficiencies may be offset when development capabilities possessed by a firm's subsystem development groups are not optimally suited to a particular weapon system. Further, empirical work shows little economies of scale in development work [3, p. 184 ff].

4. Smaller firms may make pioneering discoveries because the innovators were newcomers, not committed to existing techniques [3, p. 199]. It is possible that large organization discourages innovations but no evidence is offered except for comments from various industry sources [3, p. 200].

Peck and Scherer report that older companies have been acquiring some of the new scientifically oriented companies; in many cases, the older companies finance the newer ones. A factor mentioned earlier was the possibility that an established prime contractor might acquire a smaller development firm which has a government contract with a good probability of leading to a production contract, given the acquiring firm an advantage in the competition. While this possibility may be worth exploring, it seems unlikely. When the government awards an advanced research development contract, it is usually to the firm which will do the production work -- the EDTR contracts awarded to smaller firms are not of the type which will directly lead to production contracts, but represent earlier stages in the development of a weapons system. Any relationships between EDTR contracts received by firms which are later acquired probably occur because the contract is an indication of the acquired firm's capability in doing development work in which the government is interested.

III. The Data

The data for this study are taken from two Department of Defense publications, "100 Companies and their Subsidiary Corporations listed according to net value of Military Prime Contract Awards," (100 Company List) and "500 Military Prime Contractors listed according to net value of Military Prime Contract Awards for Experimental, Developmental, Test, and Research Work," (500 Company List), which appear annually on a fiscal year basis. A number of organizations were eliminated from the 100 Company List as not being relevant to a study of lock-in effects; these include universities, construction firms, and service organizations.

Several other adjustments were made:

1. Firms which appeared on the 100 Company List, but not on the 500 Company List, were assumed to have no EDTR awards in that year since the cutoff value for the 500 Company List is quite low and the 500 Companies account for a very large proportion of the total EDTR awards. See Table 1.

2. Firms which were on the 500 Company List, but not on the 100 Company List, were eliminated from the sample; it could not be assumed they had no further contracts because of the relatively high cutoff value for contracts and because there is a fairly large proportion of total contracts not accounted for by the 100 Companies. See Table 2.

3. In all cases, the data are for a parent company and all subsidiaries listed with the name of the parent on the 1964 100 Company List. If a merger took place within the period covered by this study, total contracts for the parents and the subsidiaries are used. This assumes the merged firm takes its contracts into the firm which acquires it.

Several problems with these data should be noted:

1. The division of contracts into EDTR and procurement is somewhat arbitrary. Frequently, some production is undertaken in connection with development, particularly advanced development. In particular, a revision in these categories took place within the period covered by this study.

Table 1

SELECTED CHARACTERISTICS OF EDTR AWARDS

	1964	1963	1962	1961	1960
Lowest EDTR Contractor on 500 Company List (Thousands of dollars)	270	308	252	231	236
% of Total EDTR accounted for by firms on 500 Company List	98.5	n.a.	98.5	98.8	98.4

Source: Various issues of Department of Defense release, "500 Military Prime Contractors listed according to net value of Military Prime Contract Awards for Experimental, Developmental, and Research Work."

Table 2

SELECTED CHARACTERISTICS OF PRIME CONTRACTS

	1964	1963	1962	1961	1960	1959
Lowest prime contractor on 100 Company List (Millions of dollars)	22.9	26.5	27.2	25.6	23.4	26.7
% of total prime contracts accounted for by 100 Company List	73.4	73.9	72.3	74.2	73.4	73.8

Source: Various issues of Department of Defense release, "100 Companies and their Subsidiary Corporations listed according to net value of Military Prime Contract Awards."

2. Eliminating firms which did not make the 100 Company List will tend to overstate the extent of locking in, since firms which received large development contracts not leading to production will tend to be eliminated. This may not be a serious problem, however, because of the Defense Department's reliance on a fairly small number of firms for its major weapons systems. On the other hand, inclusion of firms which make standard items will tend to weaken the relationship, since it is not likely that they previously received EDTR awards.

In addition to regressions for all firms having non-zero prime contracts in 1961, 1962, 1963, and 1964, individual regressions for two industries, aircraft and electronics, were run. Assignment of firms to these industries was based on Table 5A of [3]; there appeared to be sufficient observations for these two industries to warrant separate regressions.

IV. Statistical Results

Multicollinearity proved to be a very serious problem: correlations between EDTR contracts for various years were quite high, and their coefficients tended to be sensitive to the particular set of lagged variables included. But R^2's were high and statistically significant, indicating that previous EDTR contracts account for a substantial percentage of the inter-firm variance in total prime contracts and total prime contracts minus the same year's EDTR contracts (the latter variable is an attempt to measure procurement). Let us next consider the results based on data for all firms, aircraft firms, and electronics firms.

A. All Firms

Table 3 displays some of the results using P_t and $P_t - R_t$ (t = 61, 62, 63, and 64) as the dependent variables. The sensitivity of the coefficients to the particular lags included is revealed, as is the fairly unstable lag pattern. An interesting feature of the results is the importance of a few particular years' EDTR awards, almost independent of the year of the dependent variable. Thus,

Table 3

ALL FIRMS

Dependent Variable	Coefficients of: (Standard errors in parentheses) R_{64}	R_{63}	R_{62}	R_{61}	R_{60}	R_{59}	R_{58}	R_{57}	Intercept	R^2	DF	F
P_{61}					1.8254* (.3065)	-.4407 (.3774)	1.3360* (.3580)		69.58	.8824	67	167.57**
P_{61}					2.0129* (.2968)	-.7574 (.3727)	-.0168 (.5811)	2.0777* (.6993)	63.33	.8963	66	142.61**
P_{61}				1.8518* (.5373)	.3849 (.5466)	-.6943 (.3458)	-.4168 (.5508)	1.8292* (.6520)	60.56	.9123	65	135.23**
P_{62}				1.4905* (.6402)	.5436 (.6511)	-.3633 (.4119)	-.0125 (.6560)	1.0962 (.7765)	82.42	.8744	68	94.68**
P_{62}			1.4738* (.3940)	-.4740 (.7873)	1.1697* (.6196)	-.1574 (.3814)	-.7134 (.6296)	1.5271* (.7207)	80.02	.8961	67	96.31**
P_{63}			1.9204* (.4032)	.0137 (.7987)	1.3576* (.6215)	.0851 (.3816)	.7682* (.4171)		79.24	.8871	77	121.00**
P_{64}	1.0505* (.5754)	-1.1375 (.7942)	2.4729* (.7849)	-2.2686 (1.517)	2.4189* (1.099)	-.3785 (.6494)	.2442 (1.087)	.0479 (1.293)	88.18	.7295	71	23.93**
$P_{61}-R_{61}$					.9583* (.2872)	-.4271 (.3536)	1.0794* (.3355)		67.68	.7111	67	54.97**
$P_{61}-R_{61}$					1.1337* (.2782)	-.7234 (.3492)	-.2328 (.5446)	1.9436* (.6553)	61.83	.7451	66	48.23**
$P_{62}-R_{62}$				.2840 (.5966)	.7333 (.5979)	-.0103 (.3697)	.4112 (.3950		84.71	.7104	69	42.34**

Table 3 (con't.)

ALL FIRMS

Dependent Variable	Coefficients of: (Standard errors in parentheses) R_{64}	R_{63}	R_{62}	R_{61}	R_{60}	R_{59}	R_{58}	R_{57}	Intercept	R^2	DF	F
$P_{62}-R_{62}$				.1576 (.5885)	.9684 (.5985)	-.2236 (.3787)	-.4881 (.6031)	1.3886* (.7138)	80.79	.7257	68	35.98**
$P_{63}-R_{63}$			1.3622* (.4156)	-1.9589 (.8232)	1.4708* (.6406)	.0788 (.3933)	.9346* (.4299)		76.68	.7244	77	40.48**
$P_{64}-R_{64}$		-1.1615 (.7265)	2.5811* (.7194)	-2.2147 (1.284)	2.1420* (.9204)				88.93	.5189	75	20.22**

* Significantly greater than zero at 5% level.

**Significant at 5% level.

R_{62}, R_{60}, and R_{58} are usually significant in the equations in which they appear. Although not many individual coefficients are significant, the R^2's for the set of variables are high, over 70% for P_t and over 50% for $P_t - R_t$.

The fact that R^2 for $P_t - R_t$ as the dependent variable run lower than those when P_t is the dependent variable may be attributed to the serial correlation in the R_t series. However, since lagged R_t's explain over 50% of the variance in $P_{64} - R_{64}$ and over 70% of the variance of $P_t - R_t$ in the other years, these results support the existence of an important lock-in effect and gives some indication of its magnitude. In all cases, the variables taken together have a statistically significant effect.

Another interesting feature of these results is the large drop in R^2 for 1964 as compared with the earlier years. This is no doubt related to the large defense cutbacks which took place in 1964; differential effects between aircraft and electronics are pointed out below.

B. <u>Aircraft Industry Firms</u>

Again, the high R^2's indicate a strong explanatory power, although these are based on a substantially smaller number of degrees of freedom than the preceding results. An interesting characteristic of the aircraft industry lag pattern, as contrasted with the electronics pattern to be taken up next, is that coefficients of the recent past tend to be significantly different from zero, suggesting a fairly quick transition from development to procurement. Perhaps more of the development work undertaken by the aircraft firms is of the advanced development type. R_{62} seems to play a key role in the P_{62}, P_{63}, and P_{64} equations. As is the case of the all firm regressions, the R^2's for 1964 are a good deal lower than those for earlier years. It seems as though the defense cutbacks affected aircraft firms to a greater extent than the electronic firms discussed below.

Table 4

AIRCRAFT FIRMS

Dependent Variable	Coefficients of: (Standard errors in parentheses) R_{64}	R_{63}	R_{62}	R_{61}	R_{60}	R_{59}	R_{58}	R_{57}	Inter-cept	R^2	DF	F
P_{61}					1.7802* (.4994)	-.5665 (.6164)	1.8373* (.6853)		101.87	.9028	16	49.33**
P_{61}					2.1395* (.4793)	-1.0762 (.6028)	-.1142 (1.090)	2.9357* (1.352)	69.53	.9261	15	46.99**
P_{61}				3.0913* (.1269)	-.4996 (1.161)	-.7454 (.5403)	-.7540 (.9815)	1.4214 (1.327)	97.39	.9481	14	51.15**
P_{62}				2.9341* (.9912)	-.5870 (.9919)	-.3686 (.6104)			149.26	.8908	17	46.23**
P_{62}			2.1592* (.9912)	.2010 (2.213)	.3325 (1.614)	.1122 (.6731)	-2.0535 (1.720)	1.1103 (2.011)	148.98	.9218	14	27.50**
P_{63}			2.8079* (.7821)	-2.6187 (1.749)	1.8141 (1.193)	.3645 (.6573)			160.09	.8975	15	32.84**
P_{64}		-2.1336 (1.933)	3.8385* (1.729)	-2.0492 (3.185)	2.4452 (2.179)				181.58	.6840	16	8.66**
$P_{61}-R_{61}$					.9864* (.4478)	-.5446 (.5527)	1.3047* (.6145)		105.49	.7646	16	17.32**
$P_{61}-R_{61}$					1.2858* (.4389)	-.9692 (.5520)	-.3212 (.9983)	2.4458* (1.238)	78.54	.8133	15	16.34**
$P_{62}-R_{62}$				2.0369 (1.579)	-.5497 (1.444)	.0022 (.6746)	-.6267 (1.228)	-.2746 (1.646)	158.56	.7623	15	9.62**

Table 4 (con't)

AIRCRAFT FIRMS

Dependent Variable	Coefficients of: (Standard errors in parentheses)								Inter-cept	R^2	DF	F
	R_{64}	R_{63}	R_{62}	R_{61}	R_{60}	R_{59}	R_{58}	R_{57}				
$P_{63}-R_{63}$			2.2752*	-3.1219	1.8847	.3353			158.39	.7089	15	9.13**
			(.8381)	(1.874)	(1.278)	(.7043)						
$P_{64}-R_{64}$		-1.6462	3.9207*	-4.6418	3.7328*				175.21	.5124	16	4.20**
		(1.856)	(1.660)	(3.058)	(2.093)							

* Significantly greater than zero at 5% level.

**Significant at 5% level.

C. Electronics Industry Firms

These regressions, while fairly unstable, suggest the presence of some significantly longer lags, possibly indicating a longer development period. Thus, R_{61} enters significantly into the P_{64} equation; and R_{57} and R_{58} enter significantly into the P_{64} and P_{63} equations. R^2's for the electronics industry regressions drops only slightly when $P_t - R_t$ is used as the dependent variable rather than P_t, in contrast to the large changes in R^2 for the all firms and the aircraft industry regressions. Serial correlation in the electronics firms thus appears to contribute less to the explanation. In addition, R^2 does not drop greatly for 1964 as compared with the earlier years. The defense cutbacks did not affect the EDTR-prime contract relationships in the electronics firms as greatly as they affected the relationships for the aircraft firms.

V. Conclusions

Results obtained with the sample of firms in this paper are generally similar to the results obtained using the state data reported in [1]. Again the explanatory power of the equations as measured by R^2 was quite high, but the pattern of the lagged coefficients was quite variable, depending on the year of the dependent variable. A type of instability not discussed in the previous paper was the interesting and significant differences found when the data were disaggregated by industry. Using just the two crude industry categories permitted by the data, quite different patterns for the lags and responses to the 1964 defense cutbacks were found. This suggests that some degree of disaggregation is necessary before any sort of stability may be found.

The significantly high R^2 indicate a dependence of prime contracts on previous EDTR contracts; this approach thus verifies the importance of a strong lock-in effect. Research on the relation between the lock-in effect and

Table 5

ELECTRONICS FIRMS

Dependent Variable	Coefficients of: (Standard errors in parentheses)								Inter-cept	R^2	DF	F
	R_{64}	R_{63}	R_{62}	R_{61}	R_{60}	R_{59}	R_{58}	R_{57}				
P_{61}					1.4292* (.6345)	-.1839 (.6728)	1.1261* (.5469)		69.38	.8894	16	42.88**
P_{62}				.2298 (1.314)	.6869 (1.391)	.3697 (.6362)	-.5980 (.8668)	2.2836* (1.157)	70.03	.9209	14	32.60**
P_{63}			1.1480 (.6849)	1.0696 (1.148)	-.7338 (.9782)	-.3707 (.4784)	.2456 (.7982)	1.8994* (.8809)	57.26	.9648	15	68.52**
P_{63}			1.7111* (.7017)	-.4158 (1.017)	.3012 (.9446)	-.3983 (.5299)	1.6488* (.5122)		52.37	.9539	16	66.21**
P_{63}		1.1805* (.5891)	.3662 (.7367)	1.0966 (1.047)	-1.1791 (.9199)	-.0880 (.4587)	-.7307 (.8762)	3.1677* (1.023)	45.36	.9726	14	70.99**
P_{64}		1.9416* (.6381)	-1.3809 (.8183)	3.5555* (1.166)	-2.5647 (1.022)	.4933 (.5064)	-3.3204 (.9747)	5.1339* (1.134)	44.62	.9528	18	89.42**
P_{64}	1.0197* (.5278)	.4194 (.9870)	-.7605 (.8273)	3.5550* (1.087)	-2.9558 (.9737)	.5402 (.4274)	-2.5614 (.9889)	4.5104* (1.105)	44.88	.9613	17	52.78**
$P_{61}-R_{61}$					.5307 (.6352)	-.2537 (.6735)	1.0799* (.5475)		67.77	.6936	16	12.07**
$P_{62}-R_{62}$				-1.7888 (1.105)	1.8332 (1.148)	.2488 (.6147)	1.2430* (.4983)		61.21	.7926	15	13.67**
$P_{62}-R_{62}$				-.7655 (1.208)	.6914 (1.278)	.1269 (.5849)	.1614 (.7968)	1.7894 (1.064)	63.55	.8274	14	13.42**

Table 5 (con't.)

ELECTRONICS FIRMS

Dependent Variable	Coefficients of: (Standard errors in parentheses)								Intercept	R^2	DF	F
	R_{64}	R_{63}	R_{62}	R_{61}	R_{60}	R_{59}	R_{58}	R_{57}				
$P_{63}-R_{63}$			.4858 (.6058)	1.0925 (1.105)	-1.1110 (.8652)	-.1312 (.4231)	-.5815 (.7060)	2.9738* (.7792)	47.18	.9456	15	43.46**
$P_{63}-R_{63}$			1.3674* (.7613)	-1.2330 (1.104)	.5094 (1.025)	-.1744 (.5750)	1.6154* (.5557)		39.52	.8928	16	26.65**
$P_{64}-R_{64}$		.4489 (.5778)	-.7725 (.7410)	3.5551* (1.056)	-2.9483 (.9257)	.5392 (.4585)	-2.5788 (.8826)	4.5225* (1.027)	44.88	.9237	18	31.13**

* Significantly greater than zero at 5% level.

**Significant at 5% level.

the tendency for mergers was not pursued at this time, but the available data might be utilized to see whether there is any relation between the award of an EDTR contract to a firm and the probability that it will be later acquired by one of the large defense contractors.

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